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Adjusting lactation milk yield of Zimbabwean Holstein dairy cows for the joint effects of age at calving and month of calving

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Milk yield is influenced by both genetic and non–genetic factors. For accurate genetic evaluations there is need to account for these factors and quantify their effects on milk yield. The main objective of this study was to quantify the joint effects of age at calving and month of calving on lactation milk yield and to compute appropriate adjustment factors for milk yield. A total of 29 315 edited lactation records of Zimbabwean Holstein dairy cows collected from 1979 to 1994 by the Zimbabwe Dairy Herd Improvement Association (ZDHIA) were used. The data were divided into two sub–sets. The first set of 16 073 records was used to develop multiplicative age–month adjustment factors and for determination of genetic parameters. The second data set with 13 242 records was used for verification of the adjustment factors. This was done to test the effectiveness of multiplicative age–month adjustment factors which were developed in this study. An Animal Model was run in the Average Information — Restricted Maximum Likelihood (AIREML) software package. The multiplicative adjustment factors for lactation milk yield varied with age at calving and month of calving. The factors were highest in young cows (1.21), decreasing with increasing age at calving and were lowest (0.89) at mature age (72 to 84 months). After 72 to 84 months the adjustment factors started increasing. The adjustment factors were also highest (1.21) in summer (December, January and February) and lowest (0.89) in winter (May, June and July). Heritability estimates were highest for first lactation cows and were low for later lactation cows. The heritability estimates were similar for both adjusted and unadjusted records. The heritability estimates for the unadjusted records were 0.38, 0.26, 0.24 and 0.21 for first, second, second and over, and all combined lactations, respectively. The corresponding estimates for the adjusted records were 0.45, 0.25, 0.25 and 0.24. This study showed that age–month adjustments were effective. The local Holstein dairy industry is recommended to use these age–month adjustment factors developed using local data to eliminate biases in genetic evaluations. Heritabilities are high enough to practise an effective progeny test and selection scheme for milk yield.

Keywords: lactation, milk yield, holstein, dairy, calving.

Introduction

Knowledge of environmental and genetic parameters for quantitative traits such as milk yield is important in the development of sound and effective breed improvement programmes. The phenotypic expression of a quantitative trait is due to both the genetic constitution of an individual animal and the environment (non–genetic factors) under which the animal is reared.

The genetic merit of a cow for milk production is of paramount importance in dairy cattle breeding. To improve milk production there is need to select sires and dams with high estimated breeding values (EBVs) as parents of the next generation. However, EBVs cannot be measured directly. They can only be estimated from the phenotypic values of the animals. Age at calving and season (month) of calving are some of the most important environmental factors which cause variation in protein, fat and milk yields in dairy cows (Keown and Everett, 1985; Muchenje, 1996). Adjustments for such factors are essential for accurate sire and dam genetic evaluations. These adjustments are important in eliminating the environmental influences from performance records of cows (Norman et al., 1995). The need to quantify the effects of some of these non-genetic factors cannot be over-emphasized.

Zimbabwe has now taken steps through the ZDHIA to implement a national genetic evaluation programme for dairy cattle (Ngwerume *et al.*, 1995). Our previous work, (Muchenje *et al.*, 1996), showed that the joint influence of age at calving and month of calving is of vital importance in causing variation in milk yield. This study showed the need to develop age-month adjustment factors for milk yield. Utilisation of such factors will eliminate the joint influences of age and month of calving. However, the age by season adjustment factors, called the Breed Class Average (BCA) factors which are currently being used in Zimbabwe were developed in Canada which has a different environment and a different dairy cattle population. A study by Mao et *al.* (1974) clearly showed that in Canada milk yield is highest in winter (December to February) and lowest in summer (May to August). In Zimbabwe, milk yield is also highest in winter which is the period between May and August (Trigg, 1989; Makuza, 1995; Muchenje, 1996; Muchenje *et al.*, 1996). Winter/summer months in Canada differ with winter/summer months in Zimbabwe. This clearly demonstrates that it might not be correct to use the Canadian BCA's in the Zimbabwean situation. The need to quantify the influence of non-genetic factors on milk yield in Zimbabwe is justified (Ngwerume et *al.*, 1995; Muchenje *et al.*, 1996).

The main objectives of this study were to develop multiplicative age-month of calving adjustment factors for lactation milk yield and to estimate genetic parameters, before and after adjusting lactation milk yield for age-month of calving with factors developed in this study.

Materials and Method

Data

A total of 29 315 edited lactation milk yield records from 100 herds registered under the Zimbabwe Dairy Herd Improvement Association (ZDHIA) were used. The ZDHIA administers the milk recording scheme. Field data is collected from the commercial dairy producers who are under this milk recording scheme (The Statement Scheme) on a monthly basis. The recorded variables include the cow's identity and parentage, milk yield, fat percent, protein percent, somatic cell counts, age at calving, calving interval, days dry, parity and calving date. For this study, lactation milk yield was the trait of interest. Only complete (305 days) lactation records of Holstein cows which calved during the 16 year period covering 1979 to 1994 were used in this study.

In an attempt to remove incorrect records and outliers restrictions were imposed on the data. Records of cows with unknown dates of calving and age at calving, missing year of calving, herd code, month of calving, class of cow and lactation milk yield were excluded from the analyses. Days dry were subdivided into seven classes 0 to 15, 16 to 30, 31 to 45, 46 to 60, 61 to 75, 75 to 90 and 91 to 150 days. The calving interval classes were defined by 25 day intervals from day 300 except for the 426 to 600 day calving interval class. Only cows with age at calving of between 15 months to 200 months were considered. Any cow with a lactation number of greater than 12 was excluded from the analyses. The range of lactation milk yield used was 1 000 to 15 000 kg. In addition, cows with unknown parentage were deleted. Sires had to have at least two progeny.

The lactations considered in the study were: first, second, second and subsequent, and all lactations. Age at calving classes were initially defined by three -month intervals up to 42 months, six-month intervals from 42 months up to 60 months, and finally 12 month intervals from 60 months to 108 months. Cows aged 109 to 200 months were grouped into the same age class. The season classes were defined by months (January to December).

For each lactation group, the data was randomly divided into two sub–data sets by herds:

1. The first data set with a total of 16 073 records was used for (a) determining the effects of environmental (non–genetic) factors on lactation milk yield, (b) development of age–month adjustment factors, and (c) estimation of genetic parameters;
2. The second data set (13 242 records) was used for (a) verification of the effectiveness of adjustment factors developed with the first data set, and (b) re– estimation of genetic parameters.

Model

The following single trait animal model (in matrix notation) was used for analysis:

$$Y = Xb + Za + Zp + e$$

Where Y = vector of lactation milk yields.

b = vector of fixed effects of herd–year, age–month of calving, calving interval, days dry and class of cow.

X & Z = known incidence matrices relating fixed and random effects to the Y vector, respectively.

a = vector of random additive genetic effects pertaining to animal effects with a distributed as $N(0, A\sigma_a^2)$.

e = vector of random residual effects with e distributed as $N(0, I\sigma_e^2)$.

Since there were no repeated records for first lactations, the animal models for these lactations did not include permanent environmental effects, whereas the animal models for second and subsequent lactations included permanent environmental effects. In addition, the animal model for first lactation cows excluded fixed effects of calving interval and days dry from the model. The model with adjusted lactation milk yield did not have age–month as a fixed factor.

The animal model has an advantage over the sire model in that it allows for both animals in the data and parents without records to be included in the analysis so that all known additive genetic relationships among animals can be accounted for.

Statistical Analysis

An Average Information Restricted Maximum Likelihood (AIREML) algorithm (Gilmour, 1995) was used for complete genetic analyses. The number of iterations required to reach convergence ranged between three and five. The convergence criterion was set at 10^{-3}.

Calculation of age–month adjustment factors

The following formula was used to compute multiplicative age–month adjustment factors using the raw mean and the maximum likelihood solutions from the analysis of the animal model:

$$\text{Factor} = [S_0 - S_i) + X_0]/X_0$$

where: S_0 = maximum likelihood solution of base age within month j

S_i = maximum likelihood solution of the ith age within month j[1]

X_0 = Raw mean of base age within month j

The base age (age$_0$) was set at 72 months of age (mature equivalent age). This was chosen as the base age because most of the cows tended to peak at that age and it had the highest number of cows. The base month (j) was January. The solution of base age within month (S_0) was 0 kg. The raw mean lactation milk yield of base age within month (X_0) was 6 342,4 kg.

For the adjusted data sets, lactation milk yield was adjusted for age–season effects as follows:

Adjusted Milk Yield = Factor * Milk Yield.

Results

Table 1 shows some of the measures of central tendency and dispersion for lactation milk by parity.

Table 1: Descriptive statistics for lactation milk yield.

Lactation number	n	Milk yield (Kg) Maximum	Minimum	Mean	Standard deviation
1	6 694	10 490	1 375	5 626	892
2	4 808	12 200	1 687	6 386	1 055
2	9 379	13 970	1 004	6 843	1 185
All	9 390	13 970	1 004	6 471	1 143

Age–month adjustment factors

Milk yield varied with age and month of calving (Figure 1). In this study milk yield was highest in winter and lowest in summer. The multiplicative age–month factors developed in this study showed an opposite trend to age–month on lactation milk yield (Figure 2). Thus as lactation milk yield increased, age–month adjustment factors became smaller. As an example, the age–month adjustment factors were generally low in the cool dry months and in older cows, where lactation milk yields were highest. In contrast, the age– month adjustment factors were high for the hot and wet months and in young cows, where milk yields were lowest. With high lactation milk yields, age–month multiplicative adjustment factors were small and vice–versa.

Genetic Parameters

Heritability estimates for lactation milk yield were higher for first lactation cows than for cows in other lactations. Estimates were similar for the adjusted and unadjusted data (Table 2).

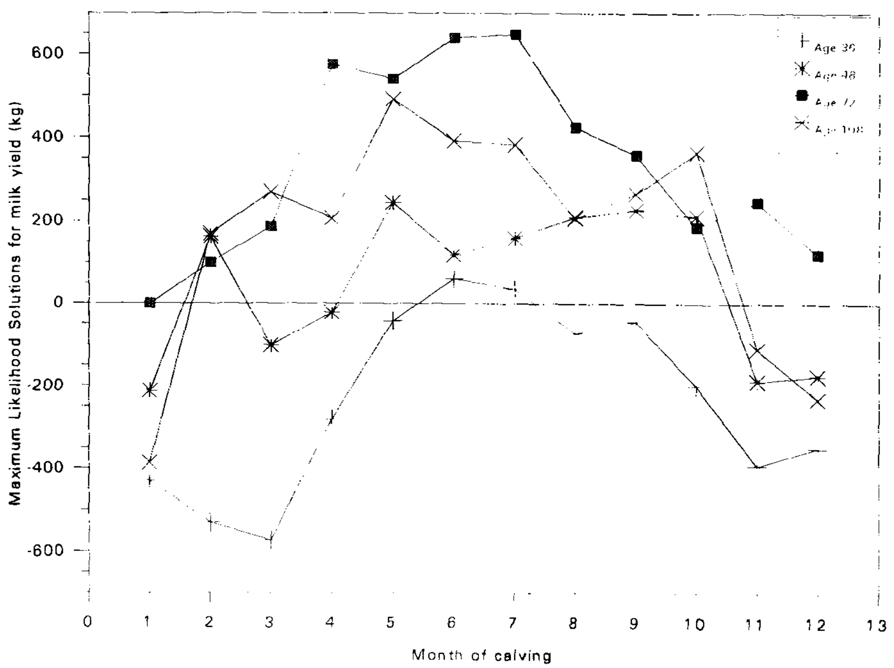

Figure 1: Effects of age-month calving on lactation milk yield for all lactations.
Source: Muchenje *et al.* (1996).

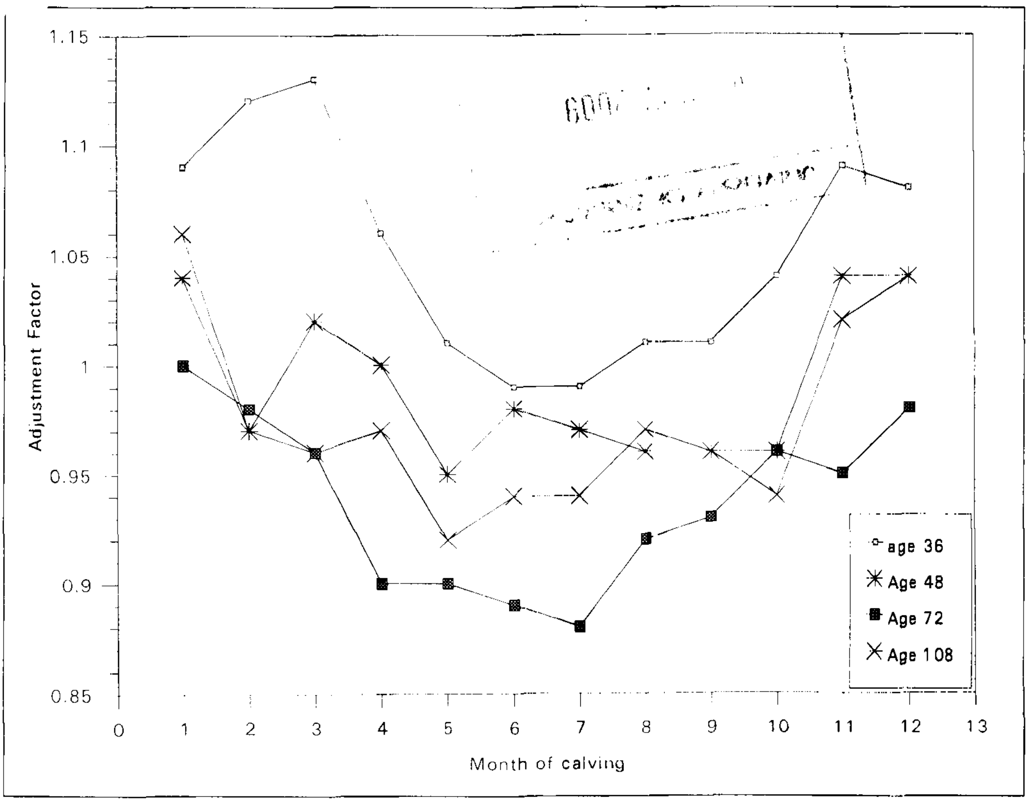

Figure 2: Age-month adjustment factors for all lactations.

Table 2: Additive (σ_a), permanent environmental (s_{pe}), residual (s_{te}) and phenotypic (s_p) variances, repeatability (rp), heritabilities (h^2) and their SE for milk yield by lactation groups of Holstein cows.

Lactation	n	Variances				r_p	h^2
		σ_a	σ_{pe}	σ_{te}	σ_p		
1: adjusted	3219	432300 ± 13090	–	535900 ± 15450	968200	–	0.45±0.011
1: unadjusted	6694	308700 ± 43210	–	503300 ± 36750	812000	–	0.38±0.047
2: adjusted	3696	237900 ± 60690	–	713800 ± 18170	951700	–	0.25±0.004
2: unadjusted	4808	287100 ± 63240	–	839300 ± 58040	1126400	–	0.26±0.053
≥: adjusted	10023	226600	180300	508300	915200	0.45	0.25±0.026
≥: unadjusted	9379	350100	326900	762900	1439900	0.47	0.24±0.027
All: ajusted	13704	224000	151400	576400	951800	0.39	0.24±0.022
:unadjusted	9390	270100	181900	867800	1319800	0.34	0.21±0.025

Discussion

Age–month adjustment factors

Use of these adjustments is important in dairy cattle improvement, especially in culling decisions where cows of different ages calving in different months are being compared. It is important to use separate age factors for each month or season of calving as milk yields varied with month (Muchenje et *al.*, 1996). For example, it would not be advisable to use the same age factor for January and June because lactation milk yields are different in these two months due to differences in environmental conditions in each of these months.

The monthly patterns observed in this study are different from those in Canada and the USA. The largest age–month adjustment factors in the USA and Canada are from May to August (Mao et *al.*, 1974; Norman *et al.*,1995) whereas in Zimbabwe the adjustment factors are lowest in these months and highest in December to February (summer in Zimbabwe). In all ages at calving lactation milk yields in Canada were higher for those cows that calved in December than those that calved in July (Mao et *al.*, 1974). This implies that the Canadian BCA's (age–season adjustment factors) for July are higher than those for December. This is opposite to what was found in this study. This clearly shows that the use of the Canadian BCA factors with Zimbabwean records will result in biased genetic evaluations. Cows calving in winter will be over-adjusted and those calving in summer will be under-adjusted. It is, therefore, recommended that age–month adjustment factors developed locally should be used in genetic evaluations. These are the most appropriate for Zimbabwe.

Age and season of calving adjustment factors have also been computed separately (Trigg; 1989, Makuza, 1995). The season factors for May through July had the lowest factors. However, these studies ignored an important age by season interaction. This work has shown the importance of considering age and season of calving jointly.

Genetic parameters

The higher ($p < 0.05$) heritability values in first lactation as compared to those of other lactation groups could be due to the improved genetics in first lactation cows as a result of genetic trends. Furthermore, first lactation cows are not yet exposed to a lot of environmental forces. Therefore, the environmental variation in first lactation is smaller than in the multiparous cows.

The above reasons could also explain why total phenotypic variation was smaller in first lactation cows than in other lactation groups. Similar results were reported in Zimbabwean Holstein and Jersey cows (Banga, 1992; Makuza, 1995) and elsewhere (Chauhan and Hayes, 1991; Misztal et *al.*, 1992; Pander *et al.*, 1992; Short *et al., 1992;* Brotherstone, 1994). This suggests that there is less environmental variation in first lactations as compared to later lactations. Powell et *al.*, (1981) also showed that heritabilities decreased with age.

It is apparent that heritability is a property not only of a character but also of the population and of environmental conditions to which the individuals are subjected. Since heritability is a ratio of magnitudes of all the components of variance, a change in anyone of these will affect it.

The repeatability values estimated in this study (0,34 to 0,47) were generally low. Similar results (0,45 to 0,46) were reported for Holsteins by Makuza (1995). These low repeatability estimates may be attributed to the fact that the procedure used in estimating the (co)variances assumes that dominance deviations and epistatic deviations are equal to zero, which may not be true. The standard errors for genetic parameters for the adjusted records were smaller ($p<0,05$) than those for the unadjusted records. This is as expected because when adjustment factors are used they tend to reduce heterogeneity in a population (Makuza, 1995).

Heritability estimates in this study indicate that rapid genetic progress can be achieved by replacing older cows in the herd by superior heifers from improved sires. This is supported by the high heritability estimates for milk yield of first lactation cows. Furthermore, by selecting early, the generation interval will be shorter, thus again increasing genetic progress per unit time.

Conclusions and Recommendations

The joint influence of age at calving and month of calving is important in lactation milk yield. There is need to use locally developed factors that would simultaneously adjust for these factors. This study has shown that the BCA factors developed in Canada are not appropriate for use in Zimbabwe. These two countries are governed by different environmental influences. The age–month of calving adjustments developed from local dairy records should increase the accuracy and precision of genetic evaluations and genetic improvement programmes in dairy cattle. Age–month adjustment factors should also be developed for other dairy cattle breeds such as the Jersey and other production traits such as fat percent and protein percent. These adjustment factors should, however, be updated regularly to account for trends that might arise due to changes in technology, feeding and general improvements in herd management. Age–month adjustment factors cannot be used across ages and months. This study has shown that adjustment factors vary with age and season of calving. For rapid genetic progress, it is recommended to replace older cows with improved first lactation cows.

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